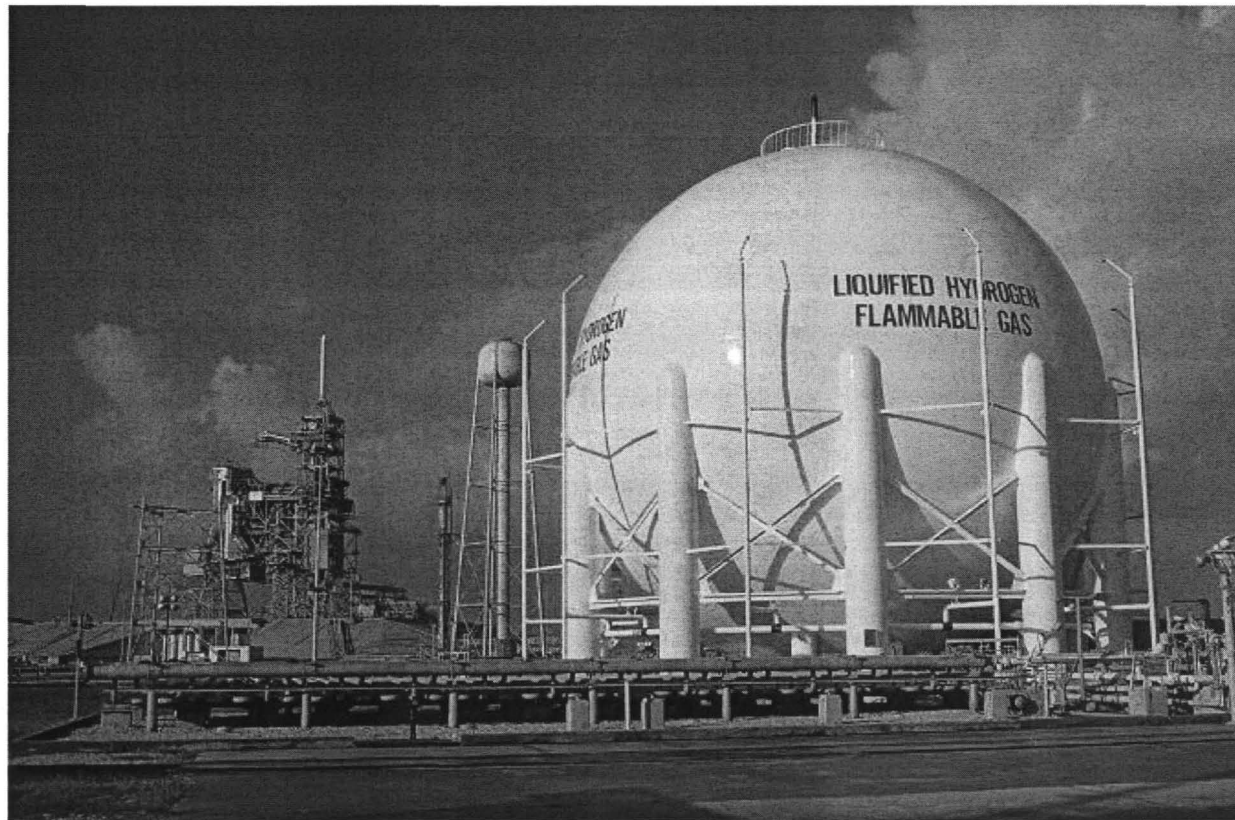




Cryogenic Storage Tank Non-Destructive Evaluation



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Cryogenic Storage Tank NDE



Included in the launch infrastructure at Kennedy Space Center are four large cryogenic tanks

- 1965 vintage, double-walled, spherical tanks with perlite insulation in the annular regions
- Two 850 kgallon LH2, Two 900 kgallon LO2
- Limited thermal life cycles

The Constellation planned to use the tanks to support the future launch efforts

- Information on the current health status of the tanks is needed to make informed decisions on the ability of these aging tanks to support a long-term launch program without risk of significant cost and schedule interruptions

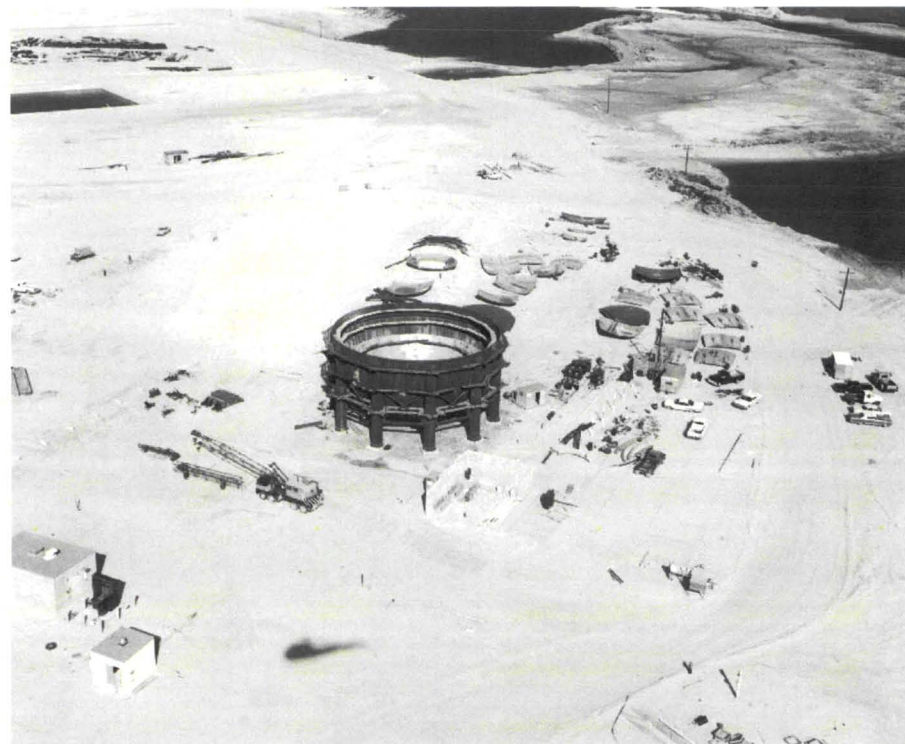
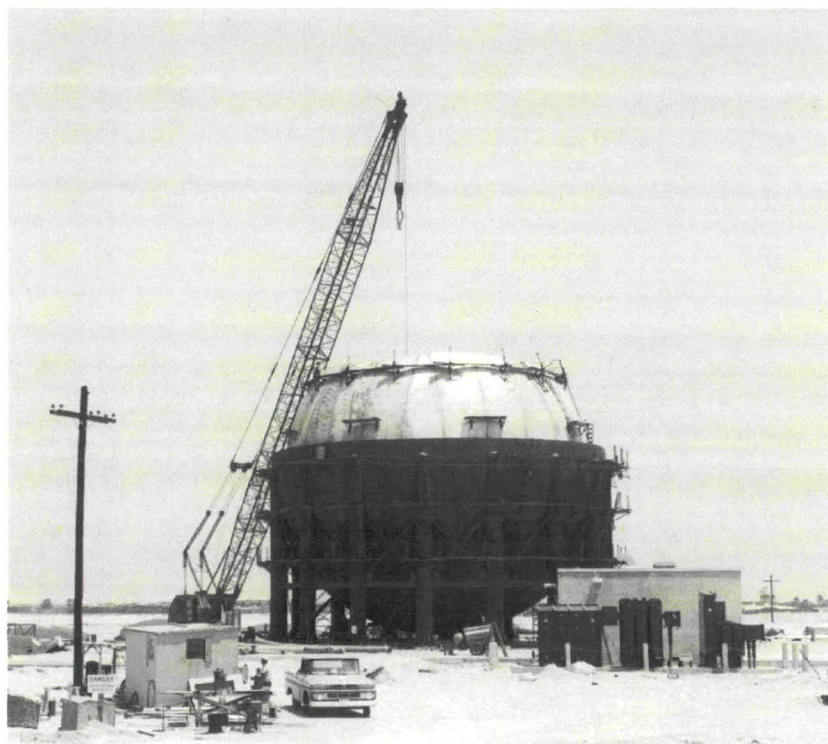


Cryogenic Storage Tank NDE– Tank Construction



LOX Tank

- 900 thousand gallon, double-walled, spherical tank
- Constructed in 1965
- Annular region filled with Perlite insulation and under slight nitrogen purge
- Inner tank supported by 165 tie rods
- Outer tank diameter is 69 feet, inner tank diameter is 63 feet

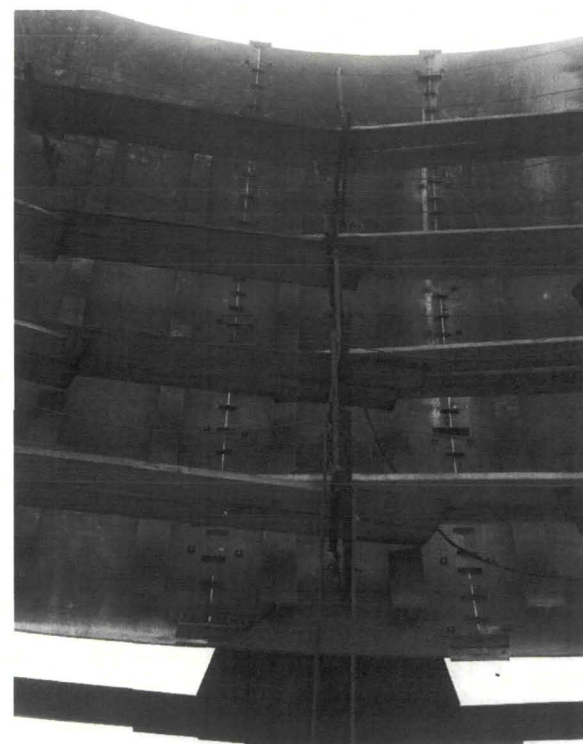
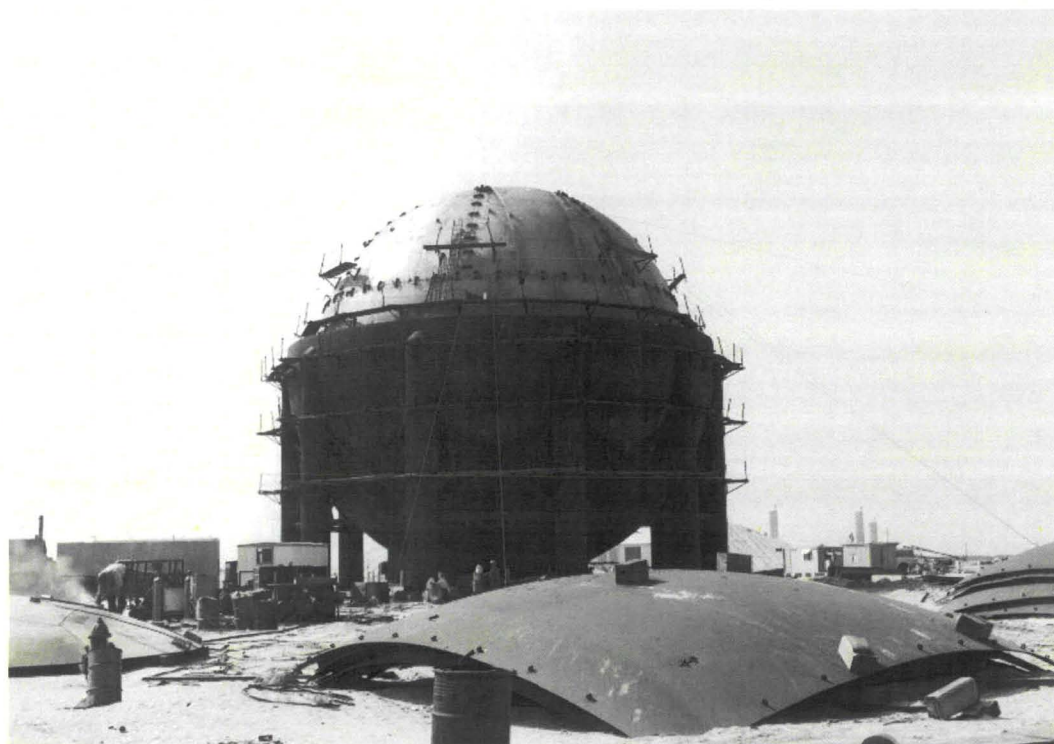


Cryogenic Storage Tank NDE– Tank Construction



LH2 Tank

- 850 thousand gallon, double-walled, spherical tank
- Constructed in 1965
- Annular region filled with Perlite insulation and under vacuum
- Inner tank supported by 40 tie rods
- Outer tank reinforced with shell stiffeners
- Outer tank diameter is 70 feet, inner tank diameter is 31 ½ feet

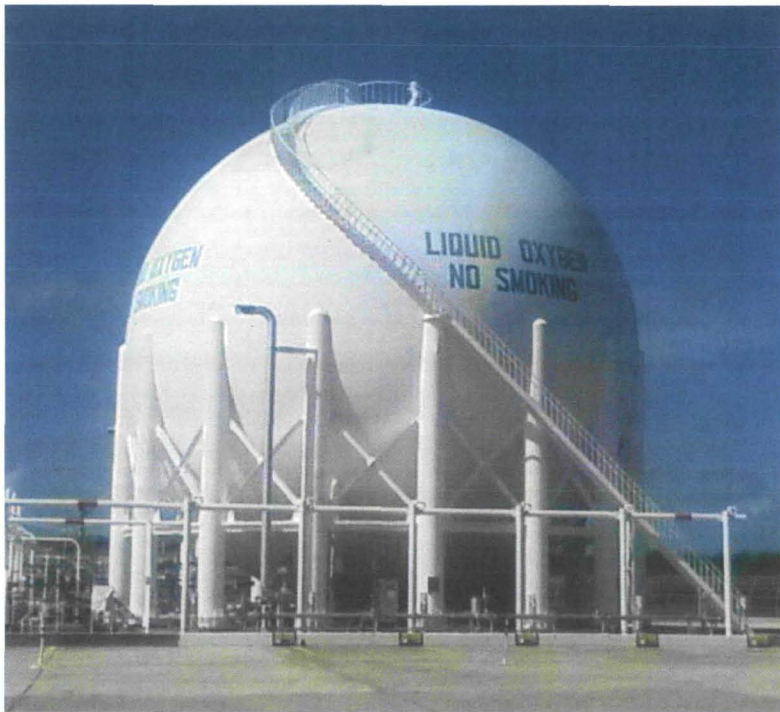


Cryogenic Storage Tank NDE– LO2 Concerns



Concerns for Pad A LO2

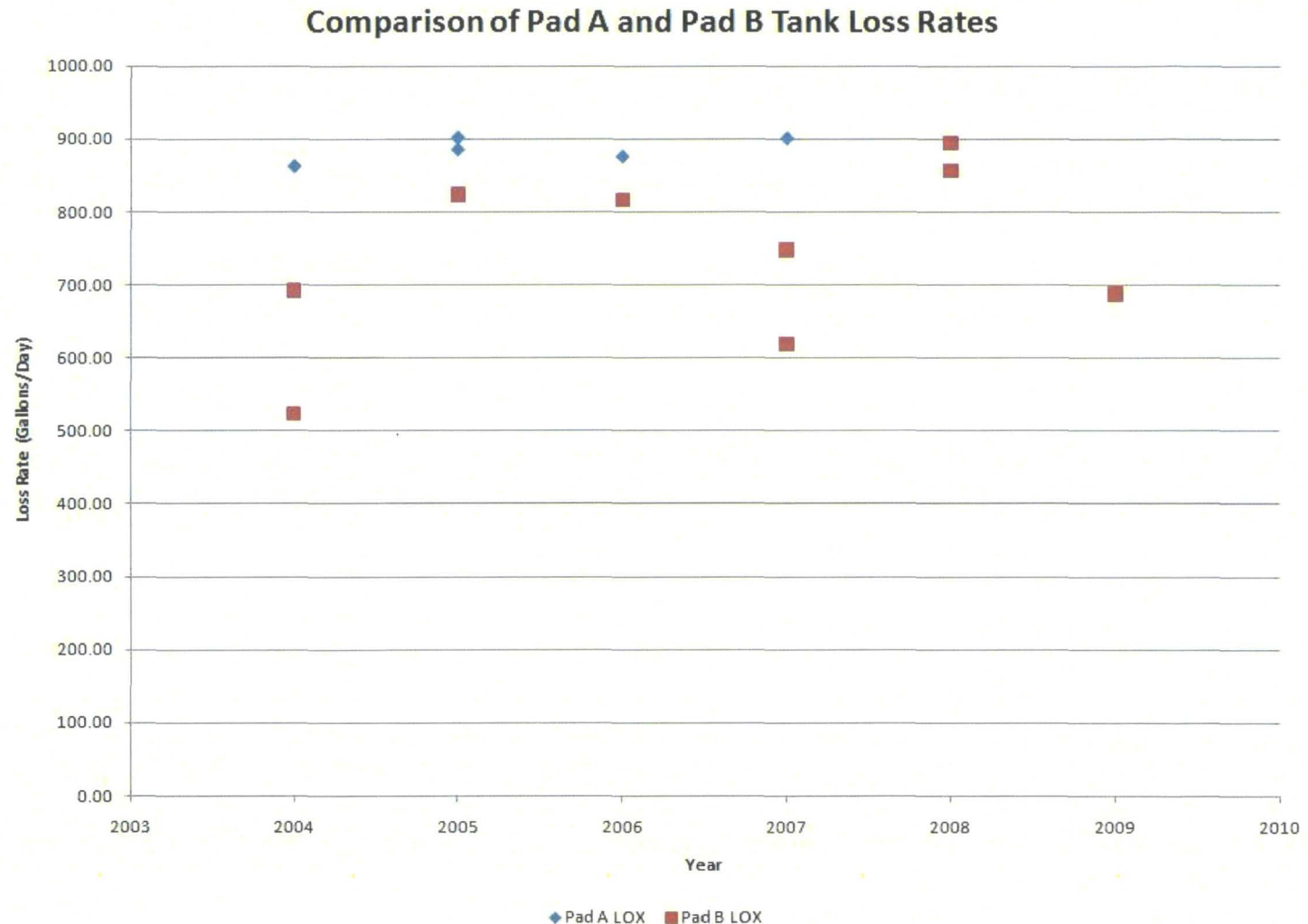
- History of Perlite settling
- Slight discoloration in localized area on the tank
- Slight increase in boil-off compared to equivalent Pad B tank



Cryogenic Storage Tank NDE- LO2 Loss Rate Comparison



- **Pad A LOX Tank Loss Rate**
 - Average 800-900 gallons per day
 - Not dependent on fill level
- **Pad B LOX Tank Loss Rate**
 - Average 600-800 gallons per day
 - Not dependent on fill level

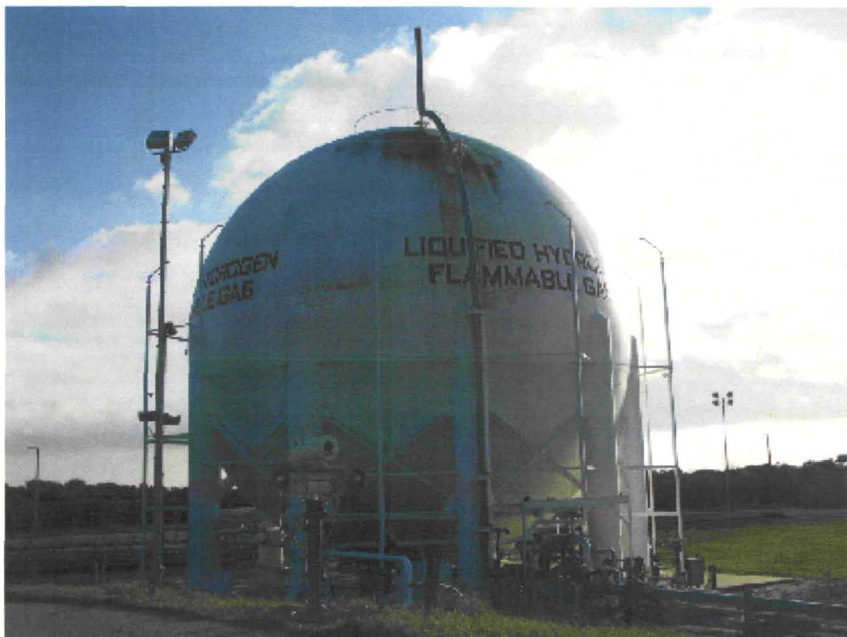


Cryogenic Storage Tank NDE– LH2 Concerns



Concerns for Pad B LH2

- Pad B LH2 Tank has an significantly higher boil-off rate than the Pad A LH2 tank
- Visible indication of increased heat flow via mold growth
- Long down-time needed for repairs
- 3 of 5 full thermal cycles have been used on the Pad B LH2 tank

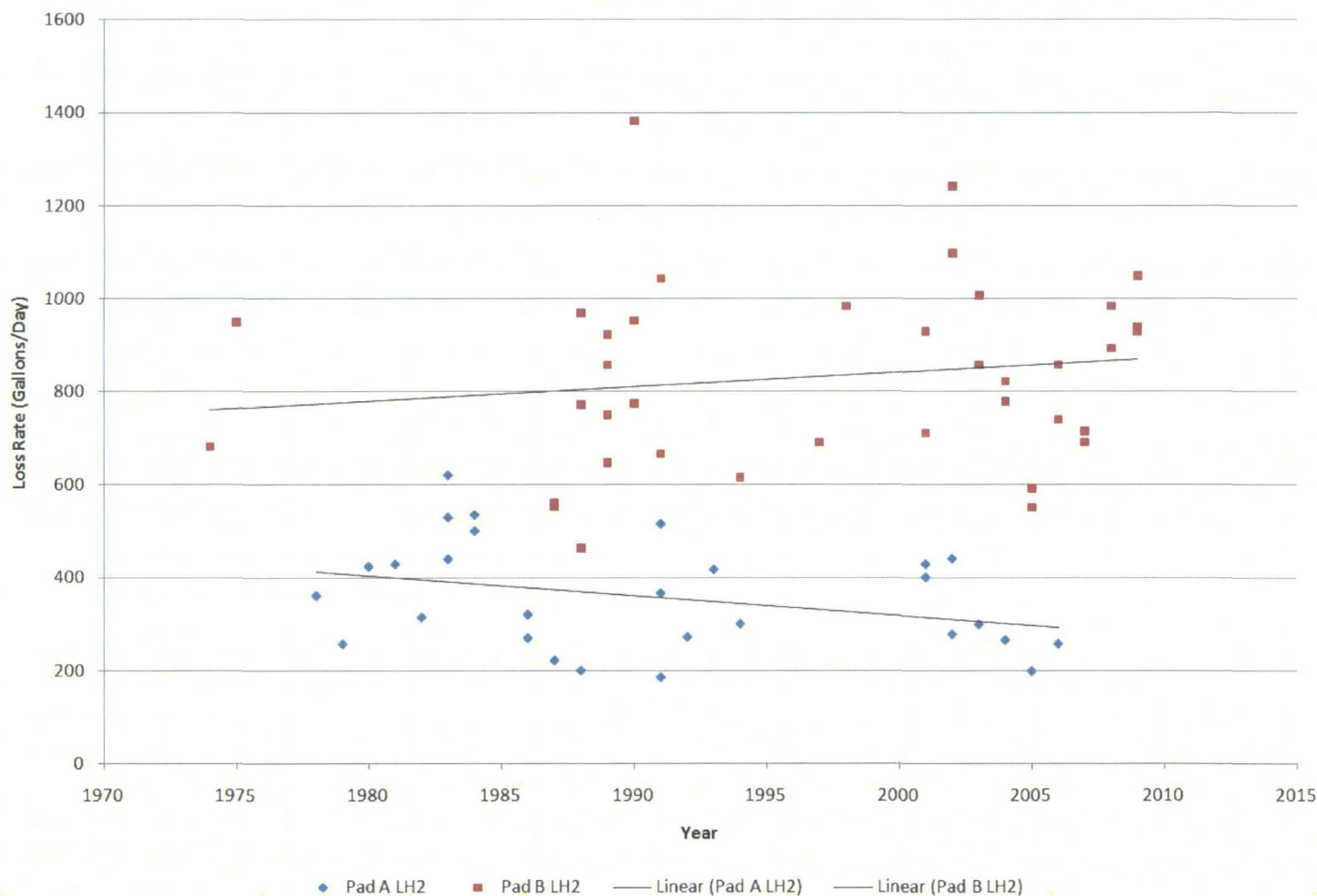


Cryogenic Storage Tank NDE- LH2 Loss Rate Comparison



- **Pad A LH2 Tank Loss Rate**
 - Average less than 400 gallons per day
 - Not dependent on fill level
- **Pad B LH2 Tank Loss Rate**
 - Between 600 and 1200 Gallons per day
 - Dependent on fill level of the tank

Comparison of Pad A and Pad B LH2 Tank Loss Rates



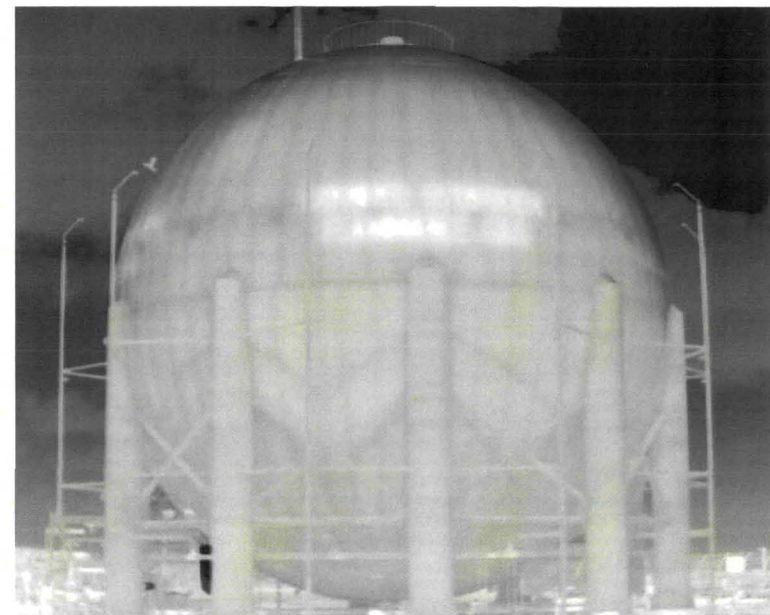
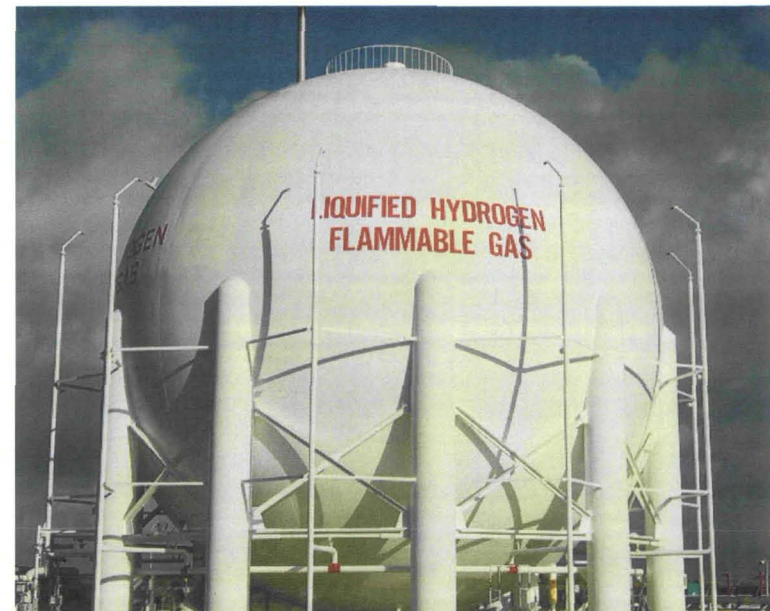
Modeling of heat transfer has shown that fill level dependence of the Pad B LH2 loss rate is likely due to an insulation void near the top of the tank and not to any structural defect.

Cryogenic Storage Tank NDE- Use as NDE



Thermal Imaging

- **Advantages:**
 - Provides efficient mechanism for analysis of large structures
 - Solar heating allows for visualization of internal structure due to the slower heating of components with larger thermal mass
 - Allows for visualization of areas of heat penetration (insulation voids)
- **Disadvantages:**
 - Results are based on discernable temperature differences and material emissivity
 - The structure on the under side of the tank is less detectable due to limited exposure to solar heating
 - Results are dependent on environmental conditions

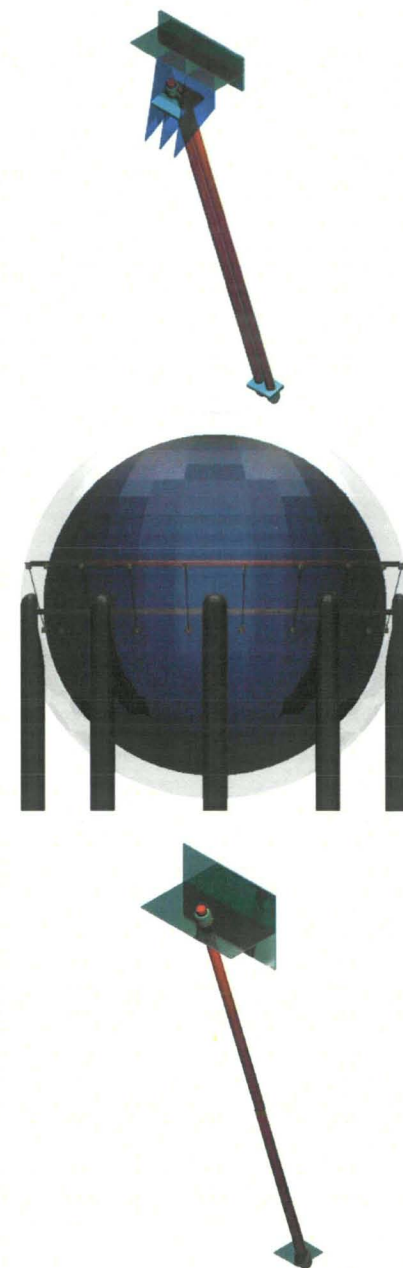
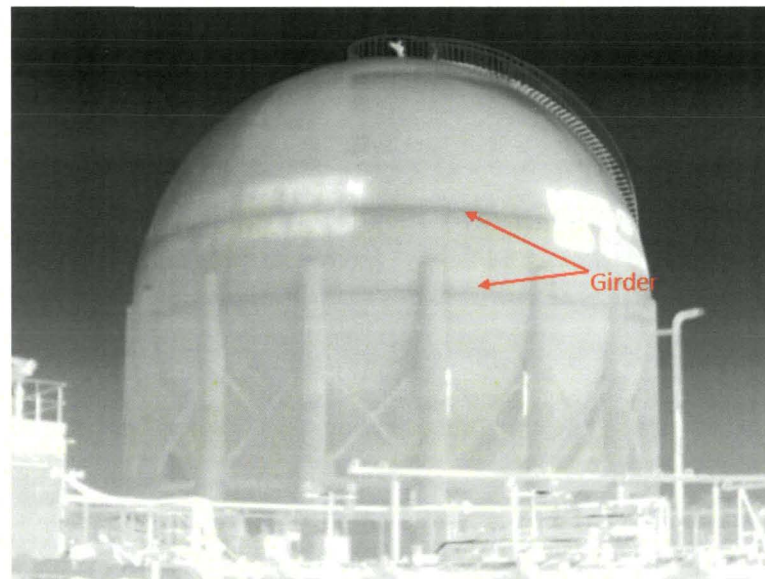
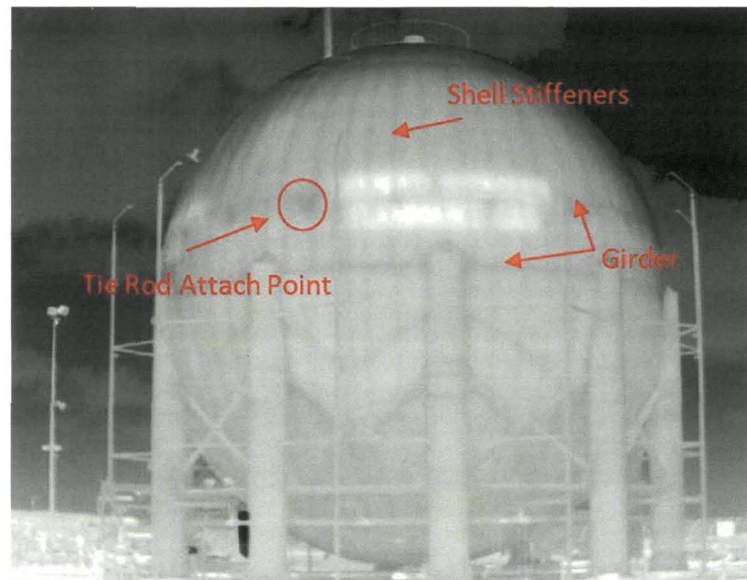


Cryogenic Storage Tank NDE– Visible Structure in the IR



Structural Elements

- Tie rods attach outer sphere to inner sphere
- LH2 40 rods at 20 attach points
- LOX tank has 165 evenly spaced
- Both tanks have stiffeners running from the upper girder to equatorial girder
- LH2 tank has stiffeners throughout the structure due to the vacuum in the annular region



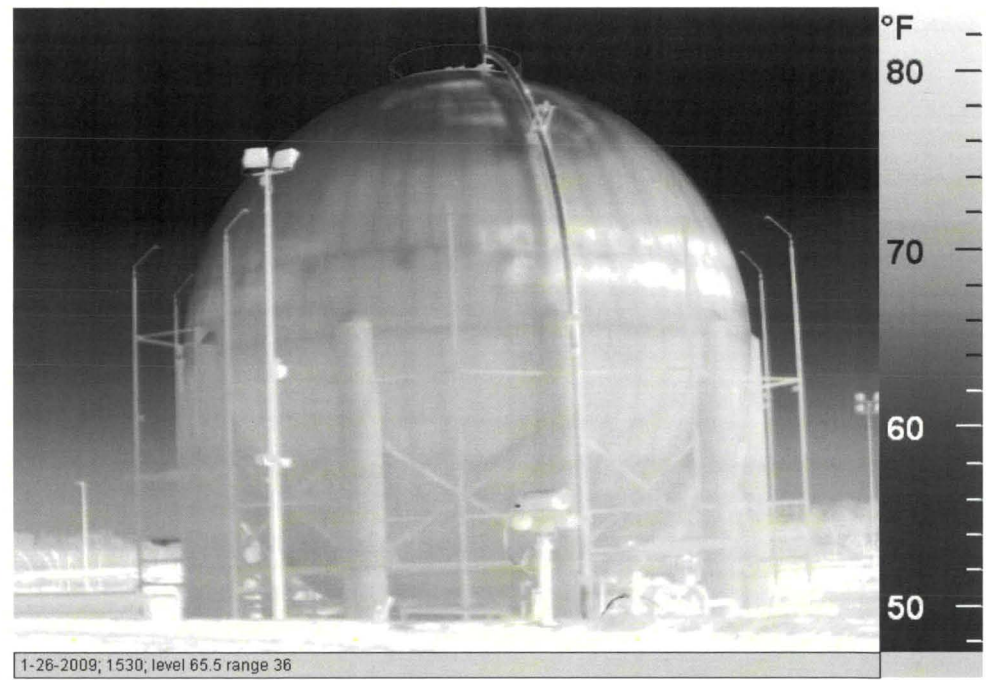
Cryogenic Storage Tank NDE– Thermal Imaging



- Thermal imaging confirms that there is a significant difference between the Pad A and B LH2 tanks
- Probable cause of “cold spot” on Pad B LH2 tank is missing perlite



Pad A LH2



Pad B LH2

Cryogenic Storage Tank NDE– Thermal Imaging



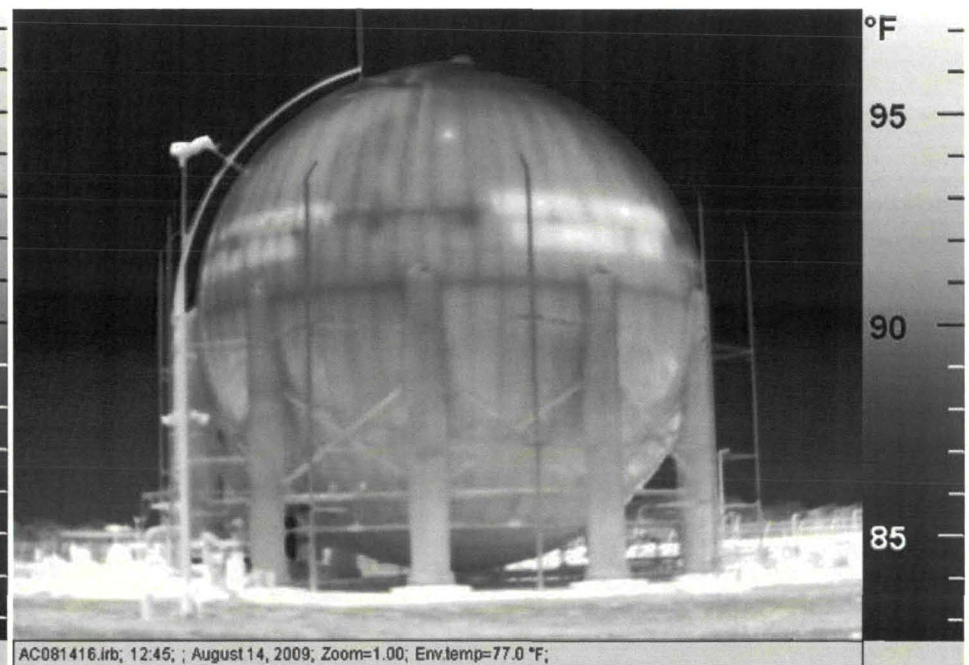
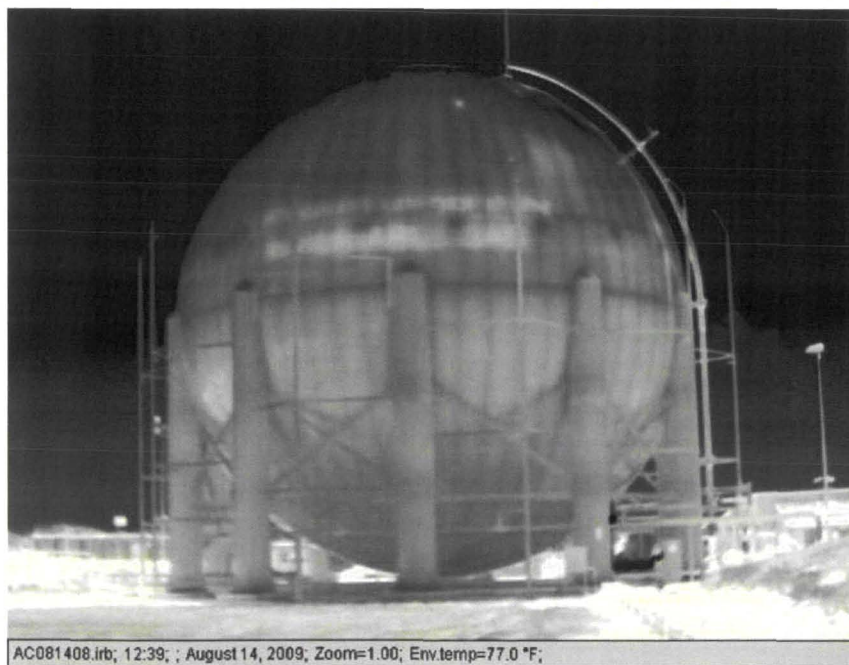
- Images were taken from all directions of the Pad A and B LH2 tanks to locate the tie rod attach points
- All twenty locations were noted in images for Pad A and B tanks (2 rods at each location for 40 rods total)
- The heat loss down the rods to the inner tank is small compared to the total heat entering the system, it would be difficult to tell through thermal analysis alone if the tie rods are attached to the inner sphere due to variations such as sun angle, wind speed, and paint emissivity



Cryogenic Storage Tank NDE – Thermal Imaging



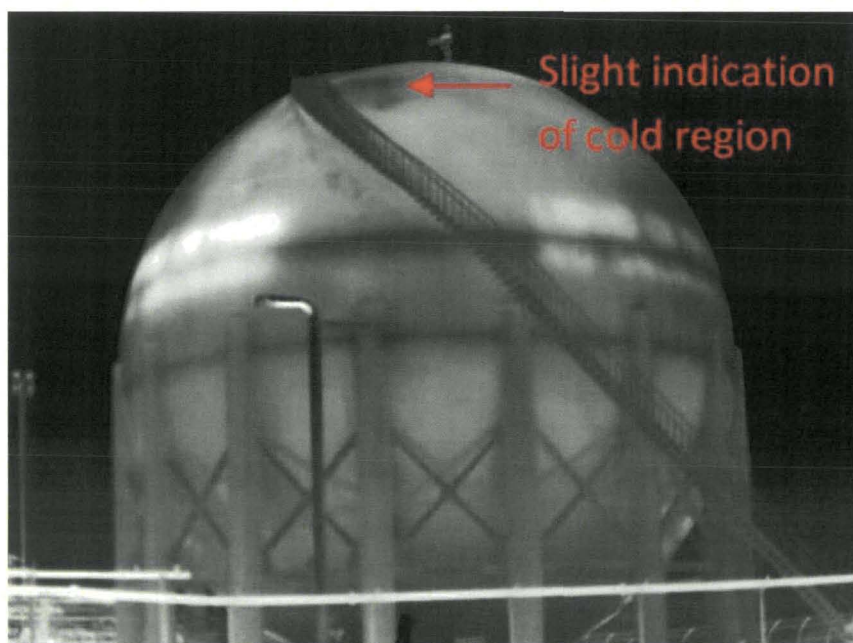
- Pad B LH2
- Images were taken at 12:30 pm on 8-14-09
- Indication of cold region near vent line on upper hemisphere, no other cold regions noted



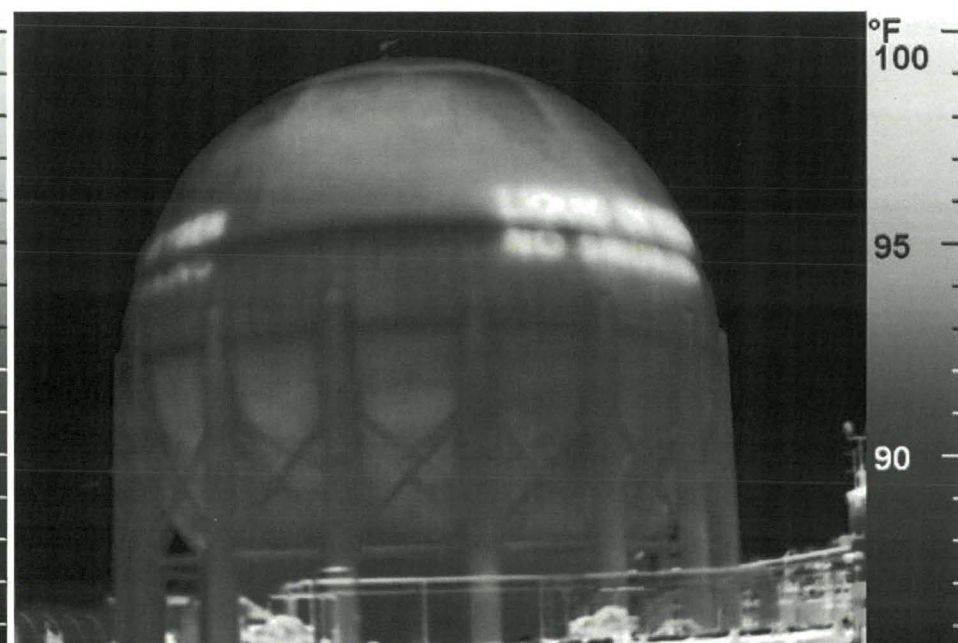
Cryogenic Storage Tank NDE– Thermal Imaging



- Pad B LOX
- Images were taken at 1:00 pm on 8-14-09
- Slight indication of a cold region above staircase on upper hemisphere



JENOPTIK Laser, Optik, Systeme GmbH : VC HiRes

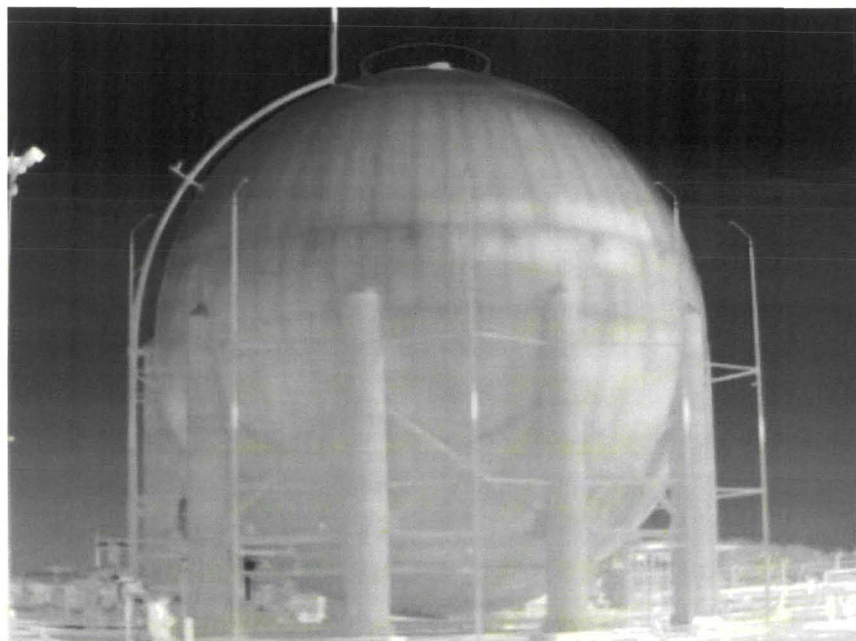


JENOPTIK Laser, Optik, Systeme GmbH : VC HiRes

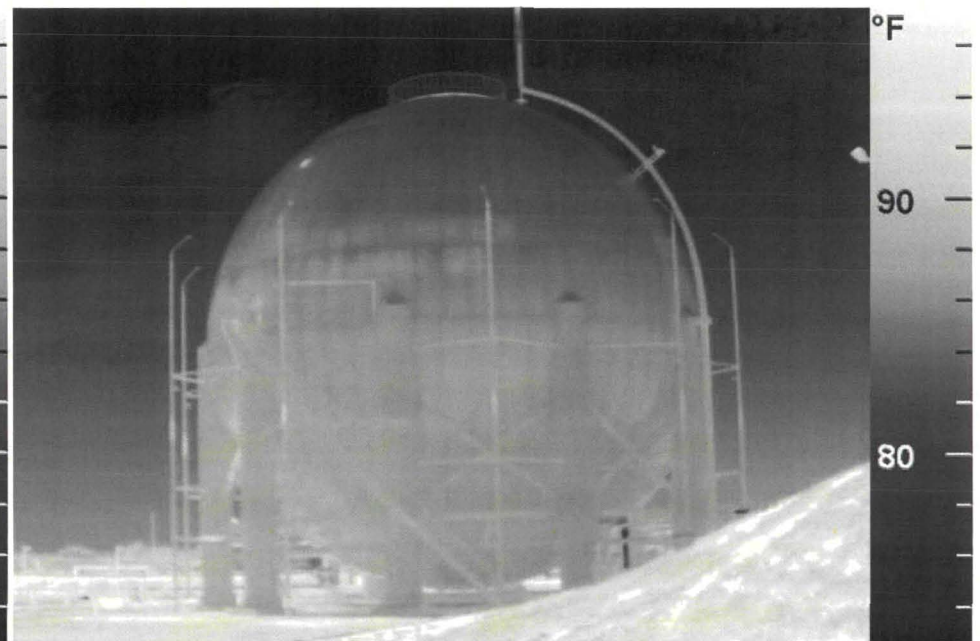
Cryogenic Storage Tank NDE– Thermal Imaging



- Pad A LH2
- Images were taken at 9:30 am on 8-19-09
- No indications of cold regions on this tank



AB081927.lrb; 09:36; ; August 19, 2009; Zoom=1.00; Env.temp=77.0 °F;

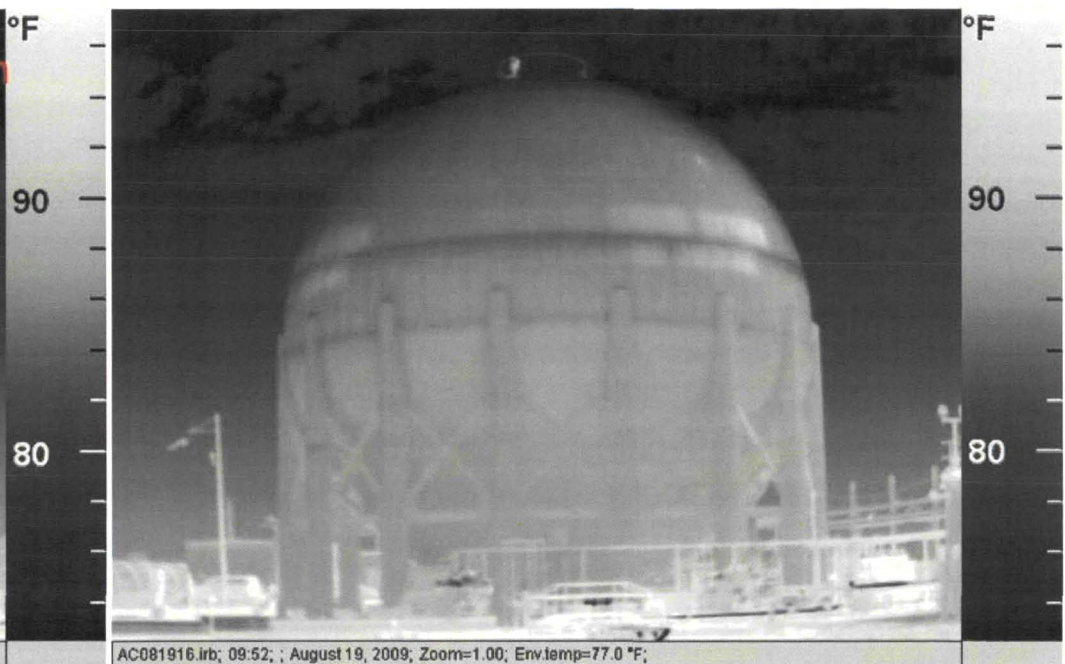
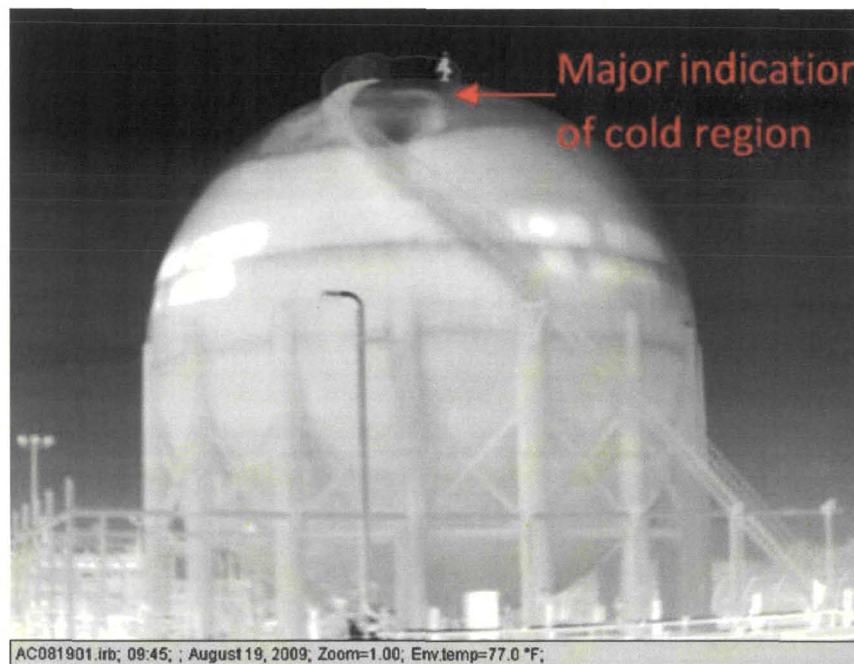


AB081916.lrb; 09:30; ; August 19, 2009; Zoom=1.00; Env.temp=77.0 °F;

Cryogenic Storage Tank NDE– Thermal Imaging



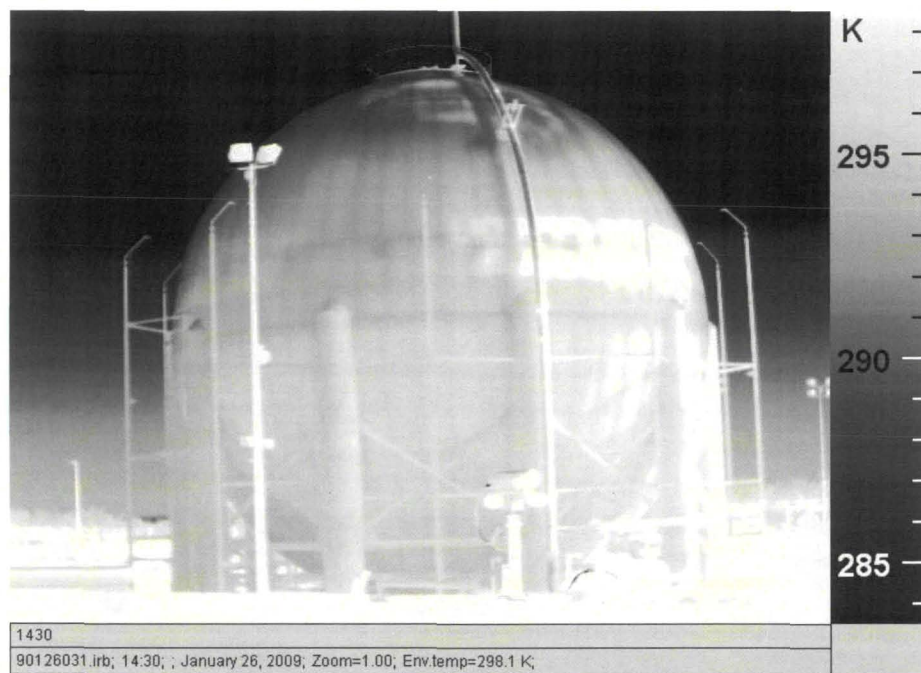
- Pad A LOX
- Images were taken at 9:45 on 8-19-09
- Definite indication of a cold region above staircase on upper hemisphere, thermal image shows region that is significantly larger than discolored area on sphere indicates; could be due to perlite compaction and settling



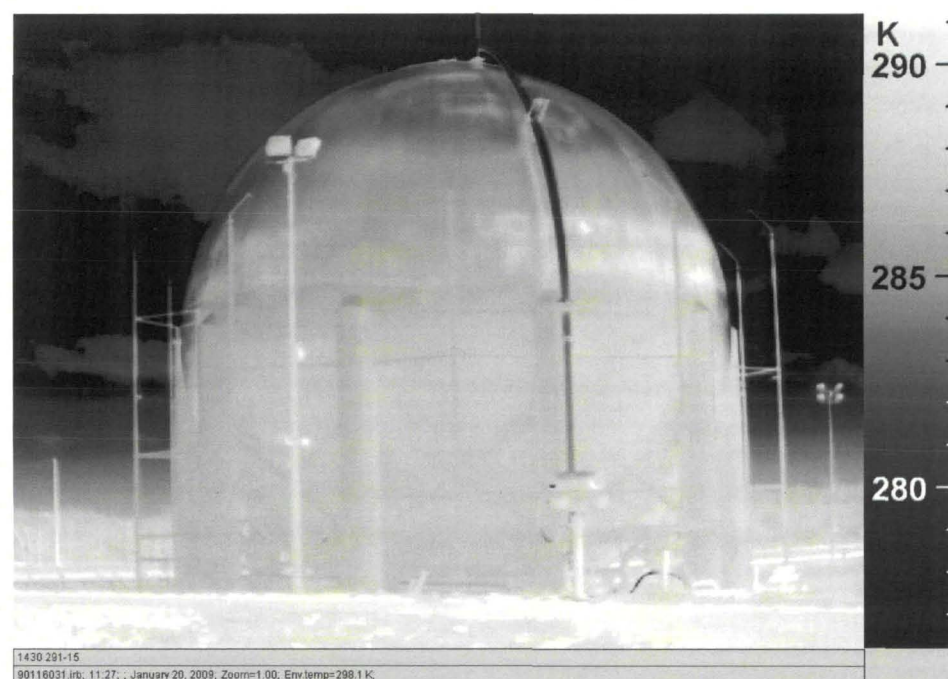
Cryogenic Storage Tank NDE– Thermal Imaging – Environmental Effects



- Thermal images can be significantly effected by environmental conditions, shown below are image differences on similar days but with different wind speeds. Other effects that were considered include ambient temperature, humidity levels/dew, cloud reflections



- 1-26-09, 2:30 pm
- 68°F
- 67% RH
- Wind Speed 8 mph



- 1-16-09, 2:30 pm
- 56°F
- 65% RH
- Wind speed 21 mph



Cryogenic Storage Tank NDE

Future – Perform thermal imaging on tanks prior to filling to look for insulation anomalies

QUESTION?

